

DOES ICT IMPROVE LEARNING AND TEACHING IN SCHOOLS?

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*A Professional User Review of
UK research undertaken for the
British Educational Research Association*

Contents

Contents	2
Acknowledgements	3
Introduction.....	4
The impact of ICT on learning and teaching: it <i>can</i> make a difference.....	5
Practice makes perfect	8
Feedback: interaction with computers	10
Multimedia: presenting and representing information in different forms.....	12
Classroom talk, pupils' thinking and computers.....	14
The challenge for the teacher.....	16
What we don't know.....	18
Appendix: The research and evidence used for the review	20

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Introduction

In the UK we have invested heavily in information and communications technology (ICT) for use by teachers and pupils in schools. Some of this investment has been directly by the government through initiatives such as the National Grid for Learning and the New Opportunities Fund ICT Training for Serving Teachers. Substantial sums have also been spent by Local Education Authorities, Education Action Zones and schools themselves on ICT equipment and resources, though this is harder to quantify. The purposes of this investment have not always been clear or made explicit. Part of the drive towards greater use of technology in education is aimed at modernizing schools and equipping the pupils of today with skills that will make them able to use such technology in the workplace once they leave school. Other stated goals have been to reduce teacher work-load by making planning and resources available over the internet or to reduce bureaucracy by providing and exchanging information in electronic form.

Perhaps the ultimate goal in promoting the use of ICT in schools has been to increase the effectiveness of teaching and improve pupils' learning. It is this goal that is the focus for the questions underpinning this review:

- What is the evidence that ICT can have a positive impact on pupils' learning in school?
- How can ICT be used effectively in schools to improve pupils' learning?

A range of sources were consulted for the review then key themes identified which emerged from this research base (see Appendix for an overview of the evidence used). A general overview of the impact of ICT on teaching and learning introduces the review and sets this research in a broader educational research context. Next, separate sections identify research evidence grouped under particular themes namely: practice; feedback and interactivity; the presentation and representation of information in different forms; classroom talk and pupils' thinking, and the role of the teacher. A final section considers issues arising from the evidence base and some of the implications from what we do not know.

The impact of ICT on learning and teaching: it *can* make a difference

There is evidence from research that ICT can help pupils to learn and teachers to teach more effectively. However there is not a simple message in such evidence that ICT will make a difference simply by being used. Findings suggest that although ICT can improve learning there are a number of issues that need to be considered if such technology is going to make a difference. Some caution is therefore called for at this broad level of where and how ICT might have an impact. There are two main issues. First is the modest effect of ICT compared with other researched interventions, second is the almost negligible effect of the provision and use of ICT at a general level.

There has been extensive research into computer-assisted instruction (CAI) and computer-based learning (CBL). Some major reviews of this extensive work have been undertaken. One study (Fletcher-Flynn and Gravatt, 1995) into the effectiveness of CAI limited the studies it examined to those that took place between 1987- 1992 and identified almost 400 reports of research that met this criteria. The impact of the use of computers was then combined statistically to identify the overall impact. In this meta-analysis the mean effect size was relatively small (.24) for the five years in question but increased for more recent studies analysed (.33). This kind of improvement would move an 'average' class of pupils from 50th to about 40th in list of 100 classes ranked in order of attainment. This suggests two things: first, it is possible that the impact of computers may be increasing; second, ICT only produces relatively small improvement. Other forms of educational interventions, such as peer tutoring, reciprocal teaching and homework, for example, all produce greater average impact (Hattie, 1987; Hattie, 1992). In a study of the effect of different types of study skills interventions the average effect size was .57 (Hattie, Biggs and Purdie, 1996); this would move a class from 50th to the top 30. A study of the effect of thinking skills or metacognitive approaches (Marzano, 1998) indicates the average impact would move a class from 50th into the top 20 (an effect size of .72).

A study by the British Educational Technology Association (BECTA, 2000) found no link between level of resources for ICT and either reading or mathematics grades at Key Stage 1 in 1999. At Key Stage 2 there was a significant, but very weak, association between ICT resources and pupil attainment. This indicated that ICT curriculum resourcing was at least 99.5% independent of pupil performance at Key Stage 2 (no correlation coefficient exceeded 0.07). In the USA, information about computer use from a longitudinal study was analysed (Weaver, 2000). This study also found a very small link between computer use in the curriculum in school and improvement in pupils' test scores, though again the link was very weak (no correlation coefficient was higher than 0.035 for mathematics, science and reading) which again indicates that at this

general level computer use makes very little difference to pupils' achievement. Simply having more computers does not make much difference.

A similar weak link between high computer use and pupil attainment was reported in a preliminary survey for a Teacher Training Agency study in England (Moseley *et al.* 1999, p 82) though the authors did not interpret this as a causal link, but rather that more effective teachers (and more effective schools) tended to use more innovative approaches, or tended to use the resources that they had more effectively. If this interpretation is accepted it suggests that it is more important to think about how computers are used in schools.

This same study also reported dramatic impact on pupil attainment in its 16 development projects in primary schools. The average gain on standardized tests was 2.8 months progress per month of the project in mathematics and 5.1 months progress per month in literacy. The report states, however, that these gains do not prove that ICT will raise attainment, but rather that "teachers *can* raise levels of pupils attainment when they use ICT to support their teaching in literacy and numeracy" (p 6). In these projects the use of ICT was planned to have an impact on particular areas of pupils' learning using research evidence from literacy and mathematics as well as the effective use of ICT. The development work involved working closely with the class teachers over an intensive period using a range of different equipment and software. These projects did not use control groups, but the consistent and significant increase in the attainment of pupils in mathematics and English suggests that where ICT is targeted at specific areas of learning, with a clear rationale for its use from a broad research base (about ICT, about pedagogy and about professional development) it can have a positive effect.

Key Messages

- Research indicates that ICT can make a difference to pupils' learning.
- In large studies there is a positive link between the provision or use of ICT resources and pupil attainment, but this link is weak.
- Analysis of targeted interventions using ICT shows a more positive picture, but not as effective as other educational innovations.
- More substantial gains in pupil attainment are achievable where the use of ICT is planned, structured and integrated effectively.

Implications

- The way that this equipment and these resources are then used by pupils and by teachers is what makes the difference.
- Other options to improve pupils' attainment should also be considered.
- Providing ICT equipment to schools or teachers will not necessarily make a difference.

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Practice makes perfect

One important factor in why pupils' attainment improves when using ICT is because they spend more time working at or practising the skills being studied and tested. Many pupils enjoy using computers and one benefit of computers may also be the combination of such motivation and the increased practice at particular tasks. Computers can therefore help by increasing the amount of time pupils spend on particular activities, by increasing pupils' motivation and engagement when doing these activities and by providing practice at an appropriate level.

There is evidence of the impact of ICT on practising skills from a wide range of studies including simple programs with a particular focus such as learning about negative numbers in mathematics (Hativa and Cohen, 1995) or early reading (Mioduser, Tur-Kaspa, and Leitner, 2000) as well as more complex Integrated Learning Systems (ILS) which have all improved pupil attainment. Some researchers have suggested that pupil practice is a crucial factor in any improvement in pupils' attainment (Van Dusen and Worthen, 1995; Underwood and Brown 1997). Software can ensure that learners are given tasks at an appropriate level that can be matched to their prior attainment or their individual needs (Lynch, Fawcett and Nicolson, 2000).

In some specific areas there is cumulative evidence of the positive impact of ICT on learning. One such area is word-processing. A systematic review (Goldberg, Russell and Cook, 2003) concluded that "on average, students who use computers when learning to write are not only more engaged and motivated in their writing, but they produce written work that is of greater length and higher quality". The effect sizes were moderate (.50 for quantity and .41 for quality) but this conclusion is based on a review of a number of studies (14 for length and 15 for quality). This kind of impact would move a class using word-processing (in the ways described in the research studies) from 50th up to 36th in a league table of 100 classes in terms of the quality of their writing. Some of the studies reviewed for this analysis integrated other approaches, such as peer-editing or included teacher feedback in the approach so it is not possible to conclude that access to word-processors alone will make a difference. There was also evidence in this review that the impact of using word-processors increased with age and that older pupils benefited more.

Use of ICT can clearly be effective in improving pupils' performance in the ways described above. However, such positive results do not help a teacher decide if the use of ICT is efficient, as other methods or approaches (e.g. reciprocal teaching) may similarly increase the amount of time pupils spend actually engaged in learning particular skills.

Key Messages

- Increased practice is a key feature of how ICT can help to improve learning.
- Computers can motivate pupils to undertake such practice and to help ensure they are practising at an appropriate level of challenge.

Implications

- Target pupils who will benefit from increased practice.
- Identify aspects of the curriculum where it is difficult to get pupils to practise and then use ICT to support this.

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Feedback: interaction with computers

There is research evidence to show that feedback from a computer can improve pupils' learning. Computer 'marking' of work in simple practice tasks across the curriculum and more sophisticated ILS programs have all produced evidence of improved pupil attainment. Feedback can, however, take very different forms. It can also be at a more general level of interaction, such as a list of websites returned from a search engine, or underlining text in a word-processor where a word is spelled incorrectly or from a computer 'talking' in response to what a pupil does.

Text-to-speech feedback in a word-processor or interactive storybook can improve early reading (Olson and Wise, 1992; Lewin, 2000). Voice input and text feedback (Miles *et al.*, 1998) can also improve pupils' reading and writing. These studies also indicate the importance of matching the tasks on a computer to pupils' current attainment. The quality of this feedback is important as, for example, second language learners may need higher quality feedback than text-to-speech generally offers (Lynch, Fawcett and Nicolson, 2000).

The quality of response is also important in a tutoring or ILS program because pupils can be learning merely how to get the best help from the system (Balacheff and Kaput, 1996). This research indicates that effective use of computer feedback in mathematics needs monitoring to ensure the pupils are learning what they are supposed to learn. In mathematics tutoring programs, for example, feedback is usually only of the number of correct responses or the total scores of performance. This type of feedback does not help pupils to correct their errors, other than by trying again. Most software does not offer formative feedback that might help pupils to identify how they could improve (Higgins, 2001). It therefore assumes that they are motivated to learn and that they know what they are supposed to be learning. This is often not the case as pupils simply want to complete the task or 'win' the game on the computer. The design of programs to support learning needs to take this into account to make sure that the teaching it aims to do is supported by learning (Atkins, 1993).

Key Messages

- Feedback from a computer can help pupils to learn in a range of different ways.
- Feedback can be misinterpreted or misused by pupils.
- Pupils' aims in using ICT may not be the same as the teacher's and this may affect the way that they interpret feedback.

Implications

- Identify what feedback a program offers and how this may help pupils learn.
- Monitor how feedback is actually being interpreted by pupils to ensure that it improves their learning.

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Multimedia: presenting and representing information in different forms

ICT is powerful in presenting or representing information in different ways. This can be through different forms (text and pictures or tables and graphs) or by enabling changes to be shown dynamically such as in mathematical modeling or by helping visualization of complex processes in science.

Information can be manipulated easily on a computer so that a pupil can make changes and evaluate the effect of those changes. This can be where the information is of the same type such as text in word-processing (Snyder, 1993; Breese *et al*, 1996) or numbers in spreadsheets (Mann and Tall, 1992); or where it is in different forms such as between tables and text (Ainsworth *et al*, 1997).

Observing changes in a graph when changes are made to the table of numerical information on which the graph is based or by manipulating an algebraic formula and observing how a graph of that function changes on a computer or graphical calculator can develop pupils' understanding of mathematical relationships.

Computer tools can help students or teachers manipulate complex data-sets. This then provides a context for effective discussion which in turn can help to develop mathematical understanding (Cobb and McClain, 2002). 'Visualisation tools' can help learners to picture scientific ideas (Jonassen, 2000) or to develop conceptual understanding.

It may be important, however, not to teach skills in isolation. Multimedia presentation in the form of talking books has been shown to improve beginning readers phonological awareness but without improving their word recognition (Chera and Wood, 2003). An interpretation of this might be that children get better at playing the computer 'game' (as they see it), but that the improved skills are not readily used away from the computer. Benefits may only come when specific improvement is supported with other learning on computers or linked to learning away from the computer and even then any improvement may only be short lived (Olson *et al*, 1997).

Key Messages

- Information on computers can usually be adapted or changed quickly and easily and this makes it possible to evaluate these changes.
- The type or medium of information can be changed or two types of information related to help pupils see connections between forms

Implications

- Computers should be used to enhance aspects of teaching through the presentation of information in different ways and in different forms.
- Pupils should manipulate and make changes to information on computers so that they can develop understanding of the relationship between different types of information or through the process of changing that information dynamically.
- Pupils should be encouraged to make connections between other learning and what they do and learn on a computer.

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Classroom talk, pupils' thinking and computers

Computers can be used individually, in small or large groups or by the teacher with the whole class. Each approach has been shown to be effective, though there are some differences in approaches and as a result upon outcomes. The difference comes in the way in which the teacher uses the different opportunities to help learners talk and think about their work.

Individuals perform better than groups when carrying out drill and practice activities (Jackson and Kutnick, 1996). This may be because they complete more on their own or because it is difficult to set tasks with an appropriate level of challenge for more than one learner. However, there is also evidence that computers can be used effectively to support pupils' talk and improve their discussion when they work in small groups on collaborative tasks (Wegerif and Scrimshaw, 1997) and even 'directive' software can support discussion and reasoning.

Teachers may need to teach pupils how to interact with each other when using the computer collaboratively so that effective learning can take place (Eraut, 1995; Dawes *et al.*, 2000). When ICT is used to promote discussion in small groups and in whole class settings this can help to develop pupils' thinking and understanding across the curriculum in a variety of subjects and with a range of outcomes. Evidence for this comes from a number of studies involving different curriculum subjects. It includes learners' mathematical thinking (McClain and Cobb, 2001), their individual reasoning (Dawes *et al.*, 2000); their higher-order thinking through ICT as a subject (Kirkwood, 2000); conceptual change in science (Eidson and Simmons, 1998) and creativity through LOGO programming (Subhi, 1999).

Key Messages

- Computers can be used effectively in a range of different ways to improve teaching and learning: by individual pupils, by groups and by the teacher to focus discussion.
- ICT can help to develop pupils' thinking in a range of different ways including reasoning, understanding and creativity.

Implications

- Grouping pupils when using computers requires a deliberate choice according to the aims of an activity.
- Effective use of ICT can support the development of understanding across the curriculum.

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The challenge for the teacher

Information and Communications Technologies present a range of tools that can be used by teachers to present and demonstrate as part of their teaching as well as something for pupils to use as part of an activity as individuals or in groups. These technological tools can be explicitly designed for use in educational contexts such as a mathematics teaching program or an overhead projecting calculator or they can be equipment and software also used in other contexts, such as computers with data-projectors or word-processors and spreadsheets. The choice of when and how to use such technologies in teaching and learning is complex. The evidence above all clearly indicates that it is *how* ICT is used that makes the difference.

Knowledge of, and experience with, computers is not enough to enable teachers to make the best use of ICT in the classroom. Effective adoption of computers within the classroom takes time (Somekh and Davis, 1997) even up to a year with the support of an experienced team or through collaborative working (Sandholtz, 2001). In addition the way in which teachers' skills, beliefs and practices are related is complex (Wild, 1996) and this in turn affects the way that teachers choose to use ICT and how effective they are at using it (Higgins and Moseley, 2001).

The final issue is that ICT changes rapidly and new innovations offer new possibilities for teaching and learning. These not only open up new techniques to influence the existing curriculum more effectively or more efficiently but change the nature of that curriculum by altering the content of what needs to be taught, such as in the area of digital literacy with use of electronic texts or the progression of how a topic like algebra can best be taught in mathematics.

The potential of new tools and opportunities can take a long time to have an impact on classroom practice. Despite the availability of word-processors in primary schools they are still used mainly to teach ICT skills rather than support aspects of writing and redrafting (Mumtaz and Hammond, 2002). The evidence supports their use (Goldberg, Russell and Cook, 2003) as discussed above. However, what prevents effective use of word-processors in schools may be more about teachers' and pupils' skills and expectations than about the availability of such technology. In addition the curriculum and its assessment act as a brake on this process of change by influencing what and how skills and knowledge are taught because of the way that they are assessed (Torrance, 1997).

Key messages

- ICT offers a wealth of possibilities to support teaching and learning.
- Effective use also depends upon the choices that a teacher makes about how to use ICT as part of their teaching.
- Technology changes rapidly and each change opens up new possibilities for teachers and learners.
- It takes time to develop the skills necessary to use ICT effectively in teaching.

Implications

- There is no single or simple solution to the effective use of ICT in teaching and learning.
- Teachers need support to develop both new technical and new pedagogical skills.
- The curriculum and its assessment need flexibility to accommodate technological change.

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What we don't know

There are a number of issues about the research and evidence on the effective use of ICT in teaching in schools. These are related to the nature of this research and pace of innovation. There are also some key things that it does not tell us. Research is rarely comparative in nature and so cannot help us to identify whether ICT is better than other approaches and this makes it difficult to decide whether the use of ICT is cost-effective. Research also rarely reports on technical issues or problems with equipment, yet these are what teachers find act as barriers to increasing the use of technology in classrooms (Moseley *et al.*, 1999).

The delay between research field-work and its publication in peer-reviewed journals is, on average, about two years (in some cases even longer). Reports in newspapers or on the internet appear more quickly. However, the findings from research are usually more cautious or may even contradict the initial reporting. For example, the internet is often heralded as a valuable teaching resource. One published study (Kramarski and Feldman, 2000) indicates that although the use of web pages may help motivate pupils, the approach is less effective than traditional instruction at improving reading comprehension and pupils' use of learning strategies. Similarly the eager adoption of Integrated Learning Systems has been tempered by more conservative research findings (Wood, 1998). Caution is therefore indicated in interpreting preliminary findings on new or emerging technologies such as the use of interactive whiteboards, mediated learning environments and e-learning.

There is little research with evidence of impact on pupil attainment. Observations in schools consistently show that ICT is typically used for drill and practice and typing up of 'a best copy' (Chalkey and Nicholas 1997; Mumtaz and Hammond, 2002). This may help to explain the generally low impact of ICT on attainment reported in the Impact 2 study (Harrison *et al.*, 2002).

It is also important to understand the aims of particular studies. Researchers often investigate computer-assisted instruction where specific content is presented to pupils. This is often from a psychological or socio-cultural perspective, which offers valuable insights into learning processes and theories. However the findings may not translate into clear messages for more effective teaching in a classroom. By contrast, when teachers carry out action research, the preferred choice is more open ended or generic software but the investigations are usually small-scale and qualitative making it hard to draw generalisable conclusions.

Key Messages

- The rapid pace of change makes it difficult to evaluate technological innovations effectively and disseminate this information quickly.
- ICT can be shown to be effective in specific areas of teaching and learning, but it is difficult to tell if it is practical or efficient.

Implications

- Teachers should be cautious of early adoption of new technologies.
- Comparative research is needed to evaluate the cost-effectiveness of ICT.

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Appendix: The research and evidence used for the review

The evidence for this review comes from a number of sources. The most important are the 200 reports and articles reviewed for the Teacher Training Agency study into Effective Pedagogy Using Information and Communications Technology for Literacy and Numeracy in Primary Schools (Moseley *et al.*, 1999, Appendix 2 pp vii-x). The project team gathered information to inform teachers' choices in using ICT to help improve pupils' attainment particularly in literacy and numeracy. Some areas, such as research into higher education and ICT were only included where it applied to schools. The search parameters from this review were then used to update the original database in Autumn 2002. This produced a further set of 215 articles and reports for material published since 1999 from the British Education Index and ERIC, a US database of educational research.

The review also draws on the database of articles collected for the Evidence and Policy Informed Practice (EPPI) systematic review of the impact of thinking skills programmes and approaches on teaching and learning (for more information please see: <http://eppi.ioe.ac.uk/EPPIWeb/home.aspx>).

In addition, research reviewed in chapters and articles written with colleagues about the use of ICT in schools provided additional information particularly for mathematics (Higgins and Mujis, 1999; Higgins, 2001a), for literacy (Higgins and Moseley, 2002), for thinking and understanding (Higgins, 2001b); in the early years (Hall and Higgins, 2002); and about teachers' thinking about ICT (Higgins and Moseley, 2001).

Research which reported empirical evidence from classroom-based research into pupil attainment in UK schools in the last 10 years was weighted strongly as this was considered to have ecological validity, though other research has been included where it was considered relevant to classroom use of ICT. The help of Rupert Wegerif is also gratefully acknowledged, particularly in the section about 'Classroom talk, pupils' thinking and computers' from discussions, exchanges of ideas and sources for his review of thinking skills and ICT for NESTA FutureLab (Wegerif, 2002).

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